GNG1103 - D

Final Design Report

Cardboard Bed Frame

Submitted by

B3, TEAM 3

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Abstract

This document will cover the design process used to develop the final product, covering the empathize, define, ideate, prototype and testing stages (EDIPT). In the first stage (empathize/define) we identified the client's wants and needs from which we began the product specification process, where we identified the problem statement and a list of prioritized design criteria. In the next stage we conceptualized design ideas (ideate). In this stage each member was responsible for formulating different designs. Taking the best three designs, we evaluated the designs using the decision making matrix and selected the best design. The next step in the design process, now having had the best design selected, involved the plan, execution and tracking of the project as well as the bill of materials. In this stage we defined the tasks, the deadline for each task, what each member was responsible for and more. The next stage (prototyping and testing) covers the three different prototypes that were created, each tested and modified based off the feedback of its predecessor. Finally, having completed this stage, there was the final solution. Based off further analysis we address what we learned and possible next steps moving forward.

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1.0 Introduction

Our client, Sandra Cocea, expressed a need for an economical bed frame for domestic violence victims in Ottawa who need a temporary place to live while the government finds a more permanent solution. Our team was tasked to create the bed frame entirely out of cardboard and we were limited to a budget of 100 dollars. It was instructed that the bed frame had to be able to support a minimum weight of 250 pounds.

1.1 Background

There is a very current problem in the city of Ottawa involving domestic violence. In many households, this is a prominent problem and there are victims looking to flee from their abusers. When fleeing, the victims often have very little money and belongings, resulting in the victims not having safe places to sleep. As a basic necessity, it is important for us as a community to work towards a solution to help these victims.

1.2 Basic User Requirements

The bed frame had to be accessible for anyone. It not only had to satisfy the design criteria, but we wanted it to be an aesthetically pleasing, comfortable bed frame, both of which were not a part of the design criteria. To do this, we made the bed sit 2 feet off of the ground and during the construction process, made sure all of the lines were drawn evenly and cutting was done meticulously.

Table 1: Specific Prioritised Needs of the Client

Rank	Needs
1	Able to support a 250 pound full grown adult without issue.
2	It needs to be stable enough to not rock or fall apart when in use.
3	It should be foldable or break down for easy transport.
4	It should support the bed at least 60cm off the ground.
5	It should be durable against liquid spills.

1.3 Key Aspects of Our Designs

Our design features many key aspects that make it stand out. Although the weight requirement was 250 lbs., our bed frame was observed to be able to handle a load of greater than 800 lbs. and is expected to be able to easily hold half a metric tonne or greater. The box shape of the legs also provide a considerable amount of storage. The location of this storage also provides a means of security for the items being stored as well as it is hidden. The design is sturdy and can last for a long time. The distribution of the forces of the frame results in an even load, meaning there are no spots that endure more stress, thus contributing to the longevity of the frame.

2.0 Need Identification and Product Specification Process

It is important to create a problem statement in order or have summarised issues, solutions and directed goal for a project. A good problem statement should give a concise idea of the overall scope of the project. During the interview with the client, the team identified the issues being faced and this was important in creating a problem statement. A good problem statement should provide an answer to the questions : what is the problem, who is experiencing the problem and what form will the solution should look like? After generating solutions for these questions, a summarised problem statement was made.

2.1 Problem Statement

In order to provide the domestic abuse victims in the city of Ottawa a safe place to sleep, a bed frame that is able to support a minimum weight of 250lbs, which can be easily compacted and transported, while being made entirely out of cardboard is needed.

2.2 Design Criteria

Taking into account the problem statement, client needs, benchmarking, metrics and target specifications, the following criterion (listed in order of greatest priority to least) were deemed necessary for a successful design:

1. The solution can support a minimum weight of 250 pounds.
2. The solution can fit a single size mattress which ideally will be 60 cm off the ground.
3. The solution is stable.

4. The design is easy and quick to operate and is not a burden for the client to assemble and disassemble.
5. The design can be compacted to a size which is around 50% smaller in volume.
6. The design is relatively light weight.
7. The solution should cost $100 at most.

After the first meeting, the list of metrics and specifications of the client was generated to better understand the requirements and constraints for design. These metrics and specifications are summarised in Table 2 and Table 3.

Table 2: Target Specifications

Metrics	Marginally Acceptable	Ideal	Reason
1	65kg/150lbs	120Kg/250lbs	Its needs to be able to support a 250 pound full grown adult without issue
2	5 years	7 years	These are estimated lifespan of a cardboard house(project)
3	10 minutes	5 minutes	It has be quick enough to avoid frustration of the client
4	92cm x 187cm	92cm x 187cm	The estimated dimensions for the bed
5	120 kg	60 kg	It has be light enough to be foldable or broken down for easy transport
6	130$ if extra budget is approved	100$	We want to fall within the budget.
7	Slightly unpleasant	Neat and simple	Product needs to be presentable.

The listed specifications defined were used to measure performance and also evaluate what we feel are the minimum requirements for the solution.

Table 3: List of Metrics

Metrics Units	Units	Client's Perception/ Technical Performance
Weight of Bedframe	Kilograms	Any sized person should be able to sleep on the bed.
Longevity of product	Years	The product needs to be durable
Time taken for bed to be assembled/Disassembled	Seconds/Minutes	Design has to be time efficient
Dimensions of the Bedroom	Centimeters	Design needs to fit the given space for the bedroom.
Easy-to-Assemble/Disassemble	Seconds/ Minutes	The design should be relatively light weight and not burden the client to move/transport the bed
Stability to transmit various loadings safely to the ground.	Newton	The bedframe should be able to resist the loads for which its designed for
Cost	CAD $	The product needs to be cost effective

3.0 Conceptual Designs

The conceptual design process is meant to distill all the ideas brought forth by the team after speaking with the client and subsequently exploring possibilities for a solution. Each solution is compared with the project metrics, analyzed for design criteria and innovation to aid in the decision process. There are a total of 13 designs, three of which had the most "ideal" characteristics. From our most ideal designs, we chose the most promising design to continue with. This is the design that was prototyped and presented to our client for feedback.

3.1 Design Ideas

Each member of the team brought forth several viable solution design ideas. The following designs were chosen as the top 3 designs to move forward with in the the benchmarking process:

Figure 1 : Design Solution Idea 1

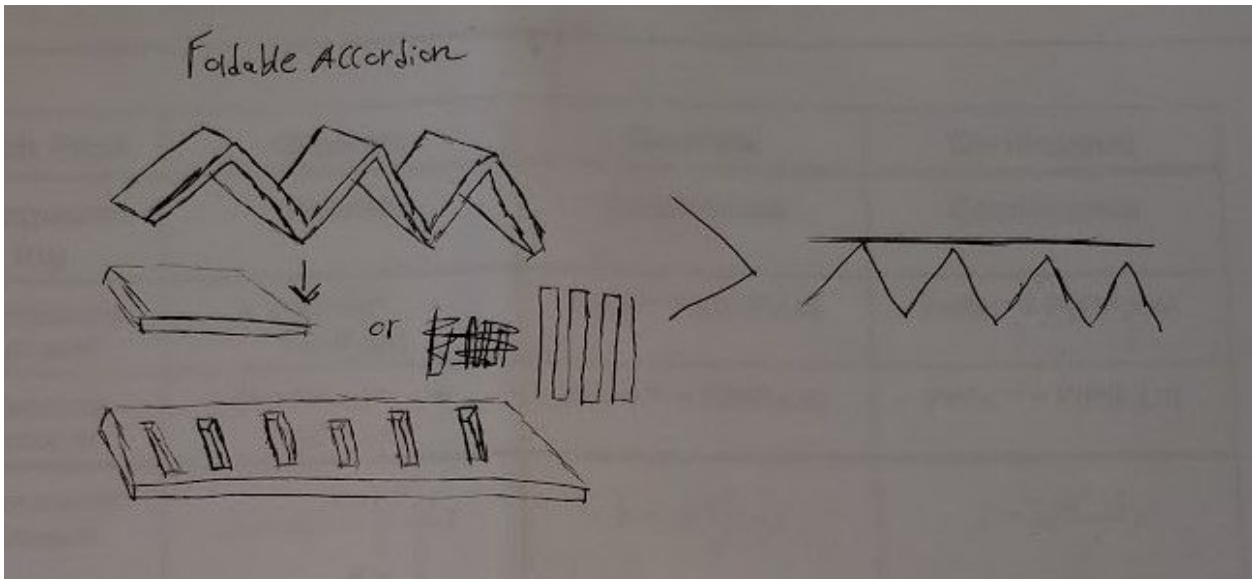


Figure 2 : Design Solution Idea 7

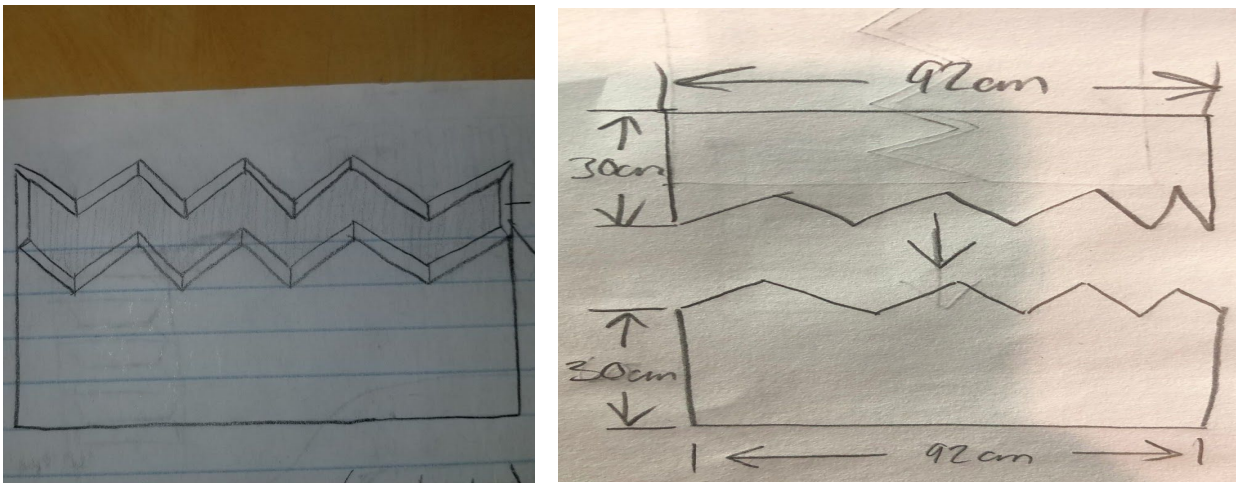
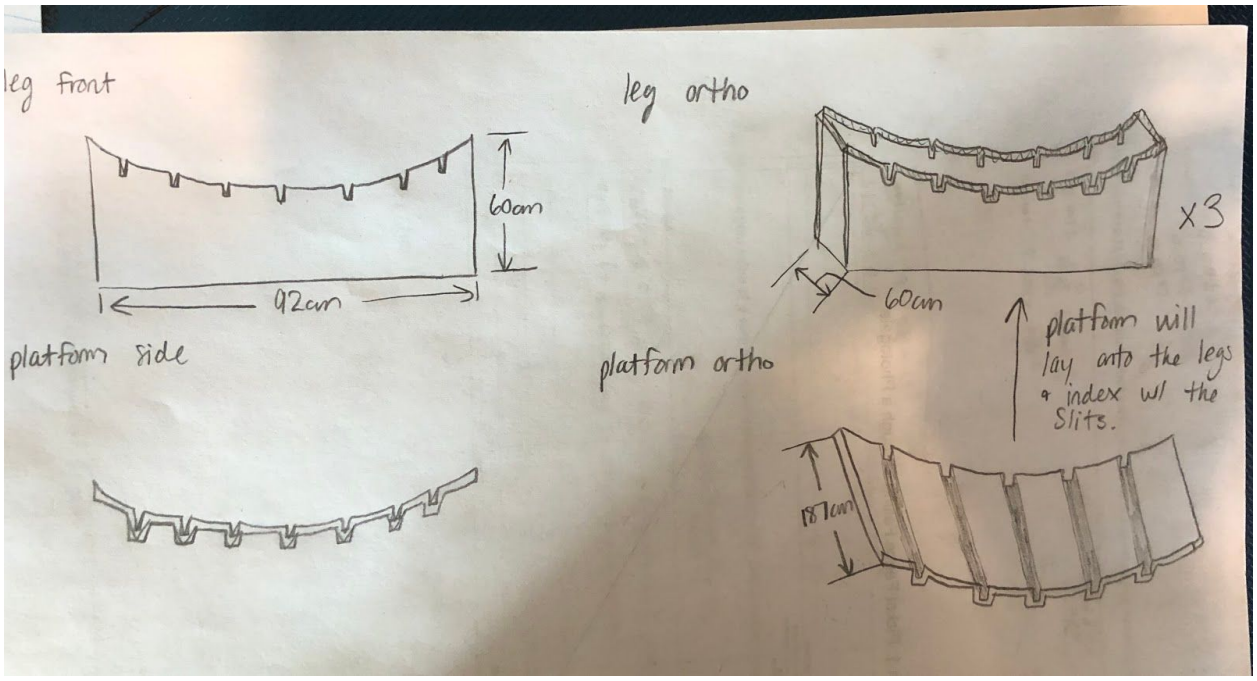


Figure 3 : Design Solution Idea 11



3.2 Benchmarking

Table 4: Decision Making Criteria for Benchmarking

Criteria	Weighting
Strength	40 %
Lifespan	20 %
Compactness Ratio	5 %
Dimensions	15 %
Ease of Assembly	5 %
Stability	10 %
Cost	5%

Table 5: Decision Making Criteria Evaluation of Performance for Benchmarking

Common Scale	
Performance Level	**Value**
Perfect	5
Very Good	4
Good	3
Satisfactory	2
Poor	1

Considering the weighting analysis performed based on the design criteria, the best design with the highest weight was idea 7 which included inspiration from idea 1 and idea 11. The team decided to use the decision matrix as it shows a clearer comparison of all design prototypes based on the given design criteria. This is much easier to understand. The rows tie into our specifications, so that when we are ranking our solutions we rank what is important for the client.

Table 6: Decision Matrix with Top 3 Design Ideas

Design Criteria (weighting)	**Idea 7**	**Idea 1**	**Idea 11**
Strength (5)	2	1	3
Longevity (3)	2	1	2
Compactness Ratio (3)	2	3	1
Dimensions (3)	2	2	2
Ease of Assembly (3)	3	2	1
Stability(5)	3	1	3
Cost (2)	1	3	1
Score	**54**	**40**	**50**

4.0 Project Plan, Execution, Tracking & Bill of Materials

4.1 Project Plan

Our project addressed the issue of the domestic abuse victims in the city of Ottawa needing a safe place to sleep. We planned on resolving this issue by producing a bed frame that is able to support a minimum weight of 250lbs, can be easily compacted and transported. In order for these characteristic to be met, deliverables were done to reach optimum results. For any solution to be accepted as viable, they had meet the technical requirements. In order to execute this project, it was essential to create a project management plan; it is a necessary building block that showcases the required steps for the success of this proposed project. This project management plan was comprised of the Work Breakdown Structure, Gantt Chart, and Project Evaluation

Review Technique Analysis (PERT Analysis) for the design phase, along with the overall project duration. It was essential to establish a logical sequence that helped complete the project activities, keep track of the project's progress, and assist in time efficiency monitoring.

4.1.1 Work Breakdown Structure

Table 7: Tasks for Project Plan

Task	Estimated Duration	Assignment	Dependencies
Conceptual Design Model	1 Day	Team	-
Client Meeting Preparation	1 Day	Team	-
Build Prototype	21 Days	Team	Conceptual Design model
Analyze prototype with client	1 Day	Team	Built Prototype
Record client feedback and satisfaction level	1 Day	Team	Analyze prototype with the client
Update prototype Design as needed	1 Day	Team	Client feedback
Prepare Final Prototype	7 Days	Team	Final prototype design

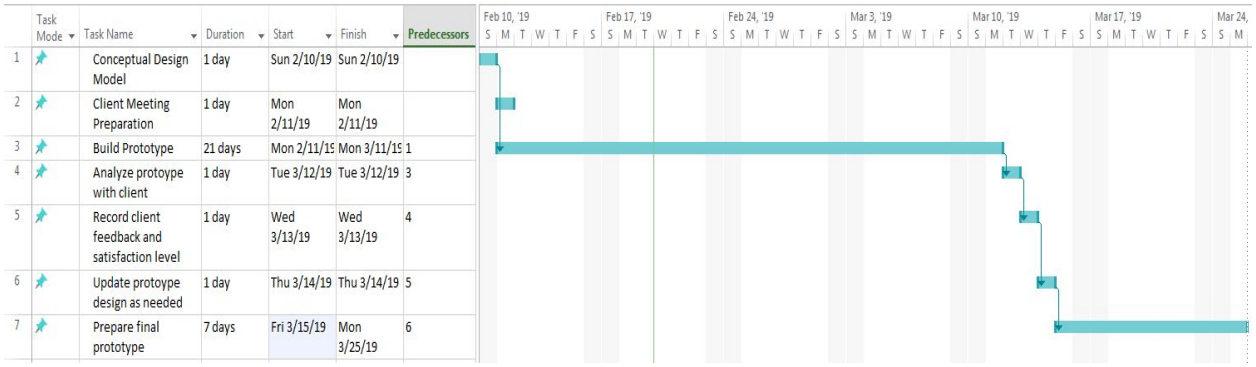
Milestones

1. Final design completed
2. First prototype completed
3. Prototype testing completed
4. Second Prototype completed
5. Third Prototype completed
6. Prototype vetted by client
7. Project Closing

4.1.2 Gantt Chart

A Gantt chart is a chart that shows the amount of work done or production completed in certain periods of time in relation to the amount planned for those periods. In the Gantt chart made for this project, a schedule with both the deliverable deadlines and the team's deadlines are shown.

Figure 4 : Gantt Chart



	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Conceptual Design Model	1 day	Sun 2/10/19	Sun 2/10/19	
2		Client Meeting Preparation	1 day	Mon 2/11/19	Mon 2/11/19	
3		Build Prototype	21 days	Mon 2/11/19	Mon 3/11/19	1
4		Analyze protoype with client	1 day	Tue 3/12/19	Tue 3/12/19	3
5		Record client feedback and satisfaction level	1 day	Wed 3/13/19	Wed 3/13/19	4
6		Update protoype design as needed	1 day	Thu 3/14/19	Thu 3/14/19	5
7		Prepare final prototype	7 days	Fri 3/15/19	Mon 3/25/19	6

4.2 Execution and Tracking

For the execution stage of the project, before we began the execution of the tasks we first had to determine any possible risks. The following is a list of the possible risks we deemed were associated with the project plan and their likeness of occuring:

1. The required materials will not be in stock (likeliness: probable)
2. The required materials will not be sold at the current price research is done at (likeliness: low)
3. The cardboard will not be strong enough to hold the minimum weight requirement (likeliness: low)

For each possible risk associated with the project plan, a corresponding contingency plan was made to mitigate/prevent the risks. The following is a list of the contingency plan for each risk, respectively:

1. Request the material to be put on hold before purchasing
2. Pre-order the material at the set price to prevent a price increase between now and buying the material
3. Switch to a stronger type of cardboard such as triple-walled corrugated cardboard

The main part of the schedule that posed as an issue was the ordering and shipping of parts for the project, as the arrival date can sometimes not be the same as the predicted arrival date . This was something our team was not able to control so in order to prevent this from being a problem the team ordered the parts early in the semester and made a backup plan if it did not arrive in time.

Although our final design was ready and presented on time, the scheduling for the project was backlogged because our build process and time of our final prototype progressed at the very last minute. This was our biggest hurdle in terms of time. The major deadlines for this project were outlined by the deliverables for the class, but within those deadlines, certain tasks had to be done in order to complete the deliverables properly

4.3 Bill of Materials

The material required to make this product are shown in the Bill of materials found in Table 7 below. The bill of materials summarises the total cost of the parts used in this project as $99.70 CAD.

Table 8: Bill of Materials (BOM)

Name	**Quantity**	**Price**	**Product Link**
Single-wall corrugated cardboard	~37400cm^2	**$**38 USD per 5x36000cm^2	https://www.staples.com/Corrugated-Sheets-96-x-60-5-Bundle-SP6096/product_1499891
Double-wall corrugated cardboard	~56000cm^2	**$**26 USD per 5x14400cm^2	https://www.staples.com/Partners-Brand-Double-Wall-Corrugated-Sheet-48-x-48-5-Bundle-SP4848DW/product_946736
Waterproof spray coating	1 can	**$**14.99/can	https://www.canadiantire.ca/en/pdp/thompson-s-waterseal-clear-wood-aerosol-protector-0482262p.0482262.html?gclid=Cj0KCQiAtbnjBRDBARIsAO3zDl-16J4a6tTj_vz0KfdDRcFIcYxDtgetOSwE7Y8Y2cHo2chKjz-5UWYaAtgdEALw_wcB&gclsrc=aw.ds#store=197
	Total:	**$ 99.70 CAD (ex. tax and shipping)**	

5.0 Analysis:

Formulas:

Volume = height * width * length

Percent Ratio = (Volume of a part / Volume of another part) * 100%

Volume of bed frame w/o mattress (includes positive and negative space):

Volume = 60 cm * 92 cm * 187 cm

= 1032240 cm^3

= 1.03224 m^3

Volume of each part alone (includes positive and negative space):

Large legs:

Volume = 92 cm * 25 cm * 60 cm

= 138000 cm^3

= 0.138 m^3

Small legs:

Volume = 90 cm * 23 cm * 60 cm

= 124200 cm^3

= 0.1242 m^3

Small slats:

Volume = 80 cm * 22 cm * 1 cm

= 1760 cm^3

= 0.00176 m^3

Large slats:

Volume = 120 cm * 22 cm * 1 cm

= 2640 cm^3

= 0.00264 m^3

Volume of bed frame in compact form (includes positive and negative space):

Volume = 2 * (large legs) + 10 * (small slats) + 10 * (large slats)

= 2 * 0.138 m^3 + 10 * 0.00176 m^3 + 10 * 0.00264 m^3

= 0.32 m^3

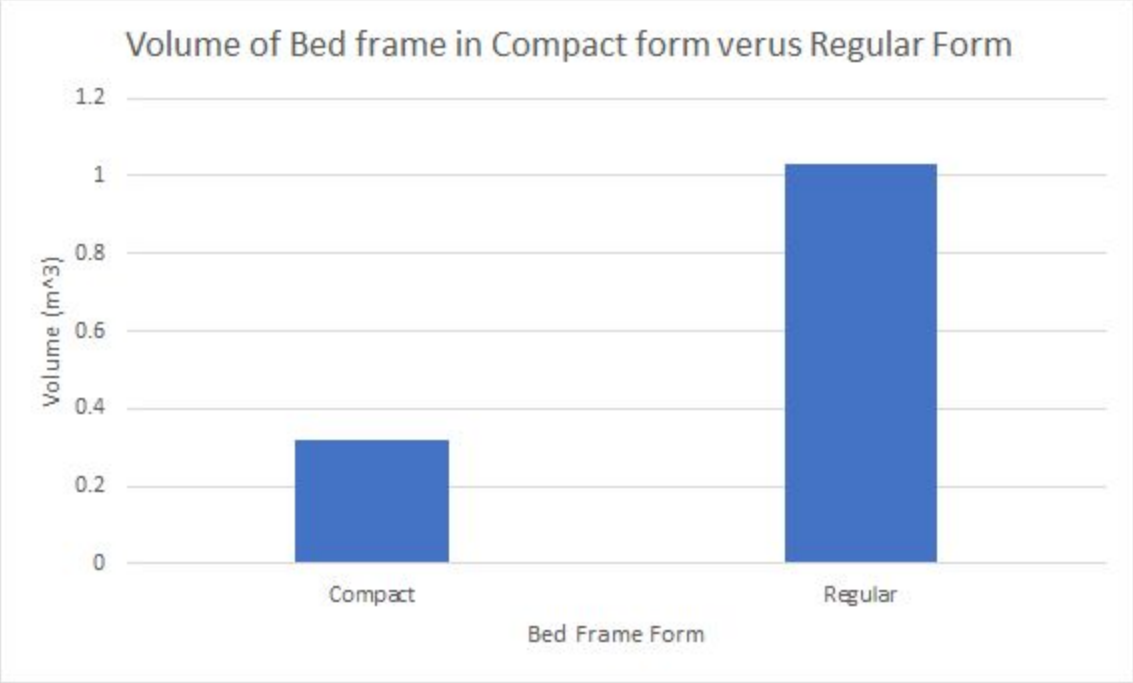
Ratio of bed frame in compact form to bed frame in regular form:

Ratio = (0.32 / 1.03224) * 100

= 31.00 %

The bed frame when in compact form is 31.00 % of the volume of the bed frame in regular form.

Figure 5 : Volume of Bed Frame in Compact Form vs. Assembled Form



6.0 Prototyping, Testing and Customer Validation.

Once the initial design and a bill of materials was established, parts ordering was commenced. After the initial prototype design, we had the opportunity to meet with the client and supervisor. In each case some feedback was provided which was used to improve the design further for the final prototype.

6.1 Client Feedback Summary

In our first meeting the client gave a description of what exactly the problem is. During the first meeting, the list of metrics and specifications of the client was generated to better understand the requirements and constraints for design. The client helped the team to figure out what the main pain points were so we could focus on those criteria and constraints. As a result the team developed a wide range of ideas for the designs.

After presenting our designs, we discovered some factors that could be ignored, and assumption that can be made which we thought were important to the design. After clarifying with our client, we decided our solution would be more efficient if we added something to prevent the mattress from sliding off the top of the frame, such as fencing in the mattress. Aswell, the client clarified that making the base of the frame water-resistant was a priority for product longevity.

In the final meeting which was the prototype II meeting we presented the supervisor with a customizable design made from pizza box parts that was able to withstand a level of strength. At the time it hadn't been human strength tested because it was our first prototype but our hypothesis proved true. The supervisor was pleased with the design and its strength and gave us the go ahead but still provided suggestions to make the design even stronger. These suggestions pertained to the legs and making them more stable as they are weak to torsional load. It was suggested to put some reinforcements within the legs so that they would hold their shape and to

close off the top of the legs with a sheet of cardboard. As a result the final product should be extremely strong.

7.0 Final Solution/ Final Design Presented to the Client

On design day the third and final prototype of the design of bed frame was presented to the client. Figure 6 shows our final prototype as presented to the client. It's important to note that our design was awarded the " Best Bed Frame ".

The legs have a corrugated top to provide strength; evenly distributing forces exerted at the points. This design involves four legs: two with the dimension 92 cm x 25cm, the other two with the dimension 90cm x 23cm. The legs are made with different dimensions so that the smaller legs can be put inside of the larger legs when in storage. The corrugated platform top can be folded up like an accordion. In terms of the metrics, the design uses minimal amounts of cardboard, making it lightweight. The structure is very strong and as a result, there is no/minimal failure points and thus making the bed frame last for a long time. The platform can be folded, making it more compact.

Figure 6: Final Assembled Design Presented to Client

Figure 7: Front View of the Bed Frame Design

Figure 8: Top View of the Bed Frame Design

8.0 Conclusions and Recommendations for Future Work

8.1 Conclusions

In conclusion the project and prototype were an overall success. The final prototype has been created with comments and concerns addressed from all the client meetings. The final prototype is functional, complete and meets all metrics set forth by the deliverables. The client is very happy with the final design because it meets all the required target specifications. The completed design was completed for less than $100. The completed design was presented on design day and demonstrated its functionality. The prototype as described within this deliverable meets the target specifications hence satisfying the clients' needs.

8.2 Recommendations

The project and prototype were an overall success, but the following comments are provided as a future direction for the project. The further improvement of the design by reinforcing the any spot that is prone to bending by adding more layers of cardboard either specifically right at the spot, or increasing the layers for the entire side of the leg to ensure longevity of the product.

Bibliography

1. Staples. (2019). *Corrugated Sheets, 96" x 60", 5/Pack*. [online] Available at: https://www.staples.com/Corrugated-Sheets-96-x-60-5-Bundle-SP6096/product_1499891 [Accessed 15 Apr. 2019].

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APPENDICES

APPENDIX I: User Manual

Parts:

1. Short slats x 15
2. Long slats x 15
3. Large legs x 2
4. Small legs x 2

Features:

- Storage inside the legs of the bed.
- Compactable bed frame, collapses into two smaller parts, takes up less volume.
- Extra strong frame, able to hold half a metric ton.

1. Lay out legs of bed such that the two outer legs are the larger legs, as shown in figure 1.

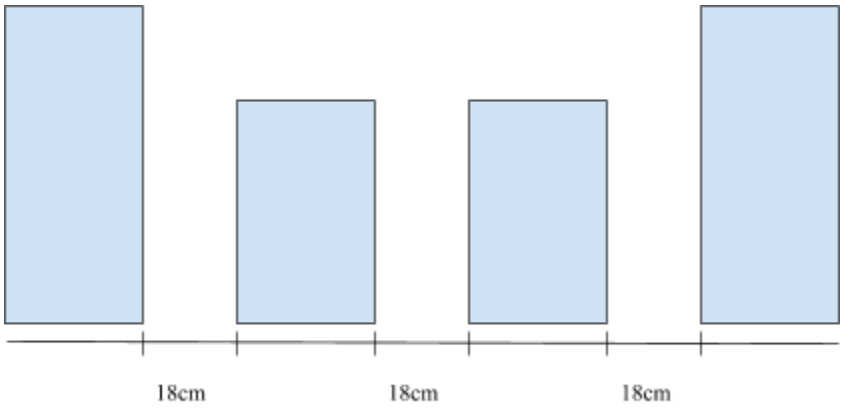

Figure 9: Side View of Frame w/o Panel

2. Lay short slats on top of the corrugated top of the legs on every triangle.
3. Lay long slats on top of the corrugated top of the legs such that the long slats reach from one end of the bed and overlap with the short slats as shown in figure 2.

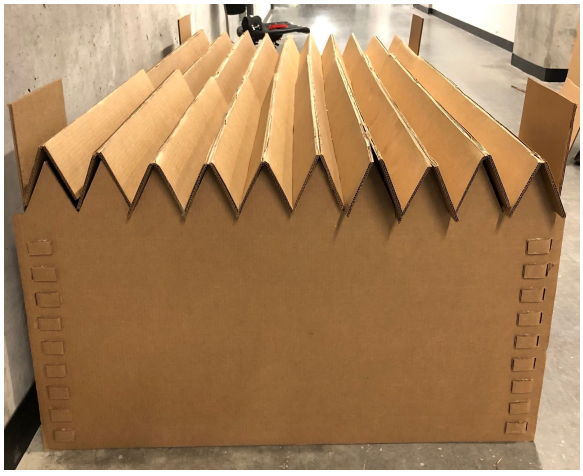

Figure 10: Long and Short slats on top of legs

4. Lay mattress on top of the bed.

Safety Hazards:

- Pressing one's hand on a sharp edge of the cardboard and running the hand across the edge may result in a deep cut.
- When sleeping on bed, if one moves too much it may result in the individual falling off the bed.

Troubleshooting:

- In event of a long or short slat breaking, extra slats have been provided. If more slats are needed than they can be cut out of two-wall corrugated cardboard.

APPENDIX II: Design Files

Include all design files with explanations so the client or other students next term can take your project to the next level. Also provide location on MakerRepo.

(All design files on MakerRepo, link below)

https://makerepo.com/jpowe074/gng1103d3cardboard-bed